ENGINEERING CASE LIBRARY

ECL 63-A

DATA INTERNATIONAL II (A)

Voltage Regulation

In February, 1964, a letter was received by DATA International of Palo Alto, California, from a missionary in Guatemala, South America, asking for help in correcting the problem of a fluctuating voltage supply at the mission. A copy of the letter is shown as Exhibit 1.

This case was prepared by Professor James W. Hill, California State College at Long Beach, during the Summer Institute on Case Methods supported by the National Science Foundation at the Stanford School of Engineering, 1966.

DATA International

DATA (Development and Technical Assistance) International is a non-profit agency staffed by eight full-time and some 30 volunteer employees. Organized as an information clearinghouse for engineering and technical problems sent in by people living and working in the less well industrialized areas throughout the world, it operates on the basic premise that the problems encountered by people in such areas can be solved if someone can find the person who has the knowledge and ingenuity to answer the particular problem. The key word here is people; this is a person-to-person problem-and-answer proposition with DATA International performing the vital function of providing the connecting link between the person with a problem and the person with an answer.

More than 135 letters a month are received by DATA, each asking help on one or more problems. These letters come from missionaries, farmers, businessmen, professors, Peace Corps workers, and others from all parts of the world.

When a request for help is received, a full-time staff member analyzes the problem to determine where an answer may be found. Inquiries are often sent to manufacturers asking for information regarding equipment or products commercially available. However, since thinking consultants might be able to suggest answers closer to the need than products currently on the market, DATA solicits their advice as well.

DATA has a list of over 1500 engineers, scientists, doctors, and other expert individuals, as well as educational institutions, industrial firms, and agencies, all volunteers, who are willing to give their time, effort, and knowledge to the solving of these problems. The customary procedure at DATA is to send a problem to at least three consultants, in order to take advantage of independent solutions. Upon receipt, the replies are air-mailed to the person who requested help.

DATA is supported solely through voluntary contributions and neither DATA nor their consultants accepts any remuneration from the people they help.

Problems answered through DATA since it was organized in 1959 have ranged from the simple (and sometimes bizarre) to the complex, from bats in the guava trees to the designing of a 50-bed hospital. While some problems may be answered by sophisticated methods and construction, most must be solved within a limited budget, using unskilled workers and locally available materials.

Mr. Douglas Hayward, Director of Projects of DATA commented, "It is expected that consultants will pay close attention to constraints and opportunities of the specific locality they are advising."

The letter from the missionary (Exhibit 1) was sent to three consultants. The consultants considered the information in the letter to be insufficient to clearly define the problem and requested additional data. Exhibits 2 through 5 are copies of letters exchanged between DATA and the missionary in an attempt to clarify the situation.

-C-O

FEB 2 1964

Exhibit 1

The Presbyterian Church in Guatemala
in cooperation with
The Commission on Ecumenical Mission and Relations
The United Presbyterian Church in the U.S.A.

THE MAM CHRISTIAN CENTER

MR. INES DIAZ, LAB. TECH.
REV. CANDELARIO PEREZ
MISS RUTH WARDELL, B.S., R.N.
REV. RALPH D. WINTER, PH.D.
MRS. ROBERTA WINTER, B.S., R.N.

San Juan Ostuncalco
Depto. de Quez.
Guatemala, C. A.

21 Feb 64

FARM
CLINIC
GRADE SCHOOL
INSTITUTE
EXTENSION
LITERATURE
LITERACY
INDUSTRIES

Dear people,

We have a hand-cranked 5 KVA adjustable transformer which accepts a degraded 220 and puts out an adjusted 110.

But the fluctuation, especially during the day is so bad that we cannot leave a refrigerator turned ~~xxx~~ on nor even a washing machine, without grave danger of ruining the motors. During the night we must adjust it at 10 PM and again at 5:30 AM, without fail, day after day, and when we leave for two days must clean out refrigerator entirely, etc.

We understand that thought the Missionary Equipment Service for some reason no longer carries automatica adjusting transformers, that there still are such both small and large.

However, it is too late. We cannot reinvest. The 5 KVA hand-adjustable transformer is what we've got, and the hope we have ~~it~~ is to improve it. I realize we cannot improve it in the sense of making its steps smaller, but I would like to ask specifically if it is possible to get some kind of voltage sensing device that would connect relays that would in turn connect up the taps in turn according to the incoming voltage. The hand operated device on our transformer is very clearly and simply connecting a single wire to one or another of 7 different taps. And I could myself connect up the relays if there is an economical sensing device that could operate them. What do you say? The whole thing, we would hope would not cost more than about $20 or $30.

Yours cordially,

Ralph D. Winter

Ralph D. Winter

RL

The Mam Indians are 250,000 modern descendants of the ancient Maya ("the most brilliant aboriginal people on this planet"), more numerous in themselves than all of the Indians in the 48 States. In the Northern Hemisphere no other Indian group as large has as high a percentage of monolingual speakers or as low an economic level. But they inhabit the cool, beautiful 8,000, to 10,000' mountains of Western Guatemala. Visitors are welcome.

Exhibit 2

APR 1 0

DATA international
437 CALIFORNIA AVENUE
PALO ALTO, CALIFORNIA

Answer Form

PROBLEM NO. 3030

YOUR ANSWER: (Please type or print)

To be of maximum value a reply should be received by 4/28/64

To our knowledge there is nothing available which can economically do the job you are seeking. An auto-transformer will perform such a function but would simply be a duplication of what you have with automatic operation. Cost for 5KVA (approx. $200.00)

($180, 5KVA manual adjustable)

What I have been thinking lately is this: we have a transformer already which, by manual operation, if you stood right by it, would handle the problem perfectly well. What we need is something mechanical which will in effect "stand right by it."

Isn't there such a thing as a voltage-sensitive device (even an ordinary voltmeter, with hairline wires the needle would swing around and touch?) that would in turn operate a set of simple relays that would in turn connect the incoming line to the right transformer tap?

Or, next best, is a voltage sensitive device which would simply protect the refrigerator--cut it out when the voltage dropped below 100 say, and cut it in again when the voltage came up to a 100. More refined still would be to cut it out if it went above 125, etc. (It can't be a manually reset device because it would have to be reset about 200 times during the day.)

Some creative thinking at exactly this point would help at least 5,000 overseas missionaries, I have no doubt at all.

If you would be willing to think further on this for us we would be deeply appreciative.

Cordially, Ralph D. Winter

Dr. Ralph D. Winter
Ostuncalco, Quez.
Guatemala, C.A.

from winter

DATA International, on behalf of the Staff, Consultants, Sponsors and Assistance Agencies co-operating, is pleased to render this problem-solving service, but must of necessity disclaim all liability for its use or application.

DATE 4/8/64

FROM Mr. Steve Lazarian, Pres.
Electric Service & Supply Co.

Exhibit 3

OCT 3 0 1964

The Presbyterian Church in Guatemala
in cooperation with
The Commission on Ecumenical Mission and Relations
The United Presbyterian Church in the U.S.A.

THE MAM CHRISTIAN CENTER

MR. INES DIAZ, LAB. TECH.
REV. CANDELARIO PEREZ
MISS RUTH WARDELL, B.S., R.N.
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FARM
CLINIC
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EXTENSION
LITERATURE
LITERACY
INDUSTRIES

San Juan Ostuncalco
Depto. de Quez.
Guatemala, C. A.

23 October 64

Data International

Dear Sirs:

Over the years I have written to you and to Missionary Equipment Service, asking technical questions about the availability of automatic voltage transformers, etc. and have been flooded with data and the general result that for our purposes there are no automatic transformers available.

I believe I have failed to put the question correctly. You may have stalled unconsciously because you wonder if I am lazy or something--why can't I reach up and turn a dial and get the voltage I want?

I'm going to try a new tack--because the problem is still with us; in fact, I seriously believe it is one of the fundamental reasons for rural areas being unable to catch up. (all over the world)

Example: in the last two months we have burned out two more transformers, and 3 motors. If we would just move our school, clinic and pilot industrial projects into the city we would have stable voltage. But we can't help the rural people, mostly indian, if we leave them or merely propose that they move elsewhere.

The problem stems from extremely fluctuating voltage: every night, every night, every night all the adjustable transformers have to be turned down. If not, as the voltage rises (from about 60v to 100v) later on in the evening, anything connected to the transformer (i.e. a refrigerator) and even the transformer itself will burn out. You can remember every night of the year and forget just one time and...out it goes. Our little projects are too many for the northamerican missionary to run around turning down the transformers.

Isn't there (here I go again with technical questions, but you now see the reason, don't you?) such a thing as a simple, rugged, cheap voltage sensing device that will break a circuit if the voltage rises or falls to much?

If only we could connect all these transformers through a relay that would open whenever the voltage rose or fell more than 15 volts, it would save us and many others hundreds of dollars and headache.

Solving this problem may actually mean the difference between closing our center down or not.

The Mam Indians are 250,000 modern descendants of the ancient Maya ("the most brilliant aboriginal people on this planet"), more numerous in themselves than all of the Indians in the 48 States. In the Northern Hemisphere no other Indian group as large has as high a percentage of monolingual speakers or as low an economic level. But they inhabit the cool, beautiful 8,000, to 10,000' mountains of Western Guatemala. Visitors are welcome.

Cordially, Ralph D. Winter

Exhibit 4

November 6, 1964

Dr. Ralph D. Winter
The Mam Cristian Center
San Juan Ostuncalco
Depto. de Quez, Guatemala

Re: Problem 3030

Dear Dr. Winter:

We trust that your good Center will remain open, even if some strange new means of automatic voltage regulator must be devised. Let's assemble our complete, basic specific facts for our consultants.

Preferably the complete information would be in the form of a rough schematic diagram of the entire electrical system, starting with the source of supply and containing

No. 1. Measured distances to refrigerator and other appliances. Also the nameplate descriptions, type, model, capacities, etc. of the appliances.

No. 2. An accurage determination of the voltage differential. You state "about 60 volts to 100 volts" which is an extremely wide range for control. As you know, a more constant range of 95 Volts to 125 Volts would make automatic control factors easier. Even if an 80 Volt step up adjustable transformer could be employed indication are that it may be overloaded.

As we have reviewed these factors piece-meal, we say only partial answers had been expressed here and there for a specific item. We must determine the whole problem to give you the proper recommendation. The answer that we both want to be right and possible must cover all.

One of the consultants who will be working on this problem with us is Mr. Earl Dickson*, an electrical engineer, who is a partner in Astrotech, Inc., and has a wide experience in electrical problems. He has inquired:

What variable transformer is now being used?
How many degrees must shaft be rotated manually to correct?
How much torque required?
Size of shaft?

You will agree, Dr. Winter, that all the above information will put us in a far better position to correctly assist you.

Thank you for the thine things you do there for us.

Cordially,

WJK:DKH:RM

*Name and company disguised

Exhibit 5

JAN 2 9 1965

La Iglesia Evangélica Presbiteriana Nacional de Guatemala
en cooperación con la Iglesia Presbiteriana Unida de EE.UU.

CENTRO EVANGELICO MAM

Instituto
Escuela Rural
Clínica
Literatura
Alfabetización
Agricultura
Industrias
Extensión

San Juan Ostuncalco
Depto. de Quez.
Guatemala, C. A.
26 de enero de 1965

#3030

Douglas K. Hayward
Data International
437 California Ave.
Palo Alto, Calif.

#3295

Dear Sir:

You will note on your enclosed airform letter that Mr. Kuhl has found a man in the furniture business to come and help us.

Regarding your letter of November 6 on problem #3030: The reason we have not answered your letter sooner is that the information you requested would have taken about an hour to gather, which would have been all right if we had been sure that it was necessary to find out, for example, the amount of torque necessary to job the mechanical control on our present variable transformer. I am willing to measure that if it seems that that is really necessary to do, but I would like to know first of all if it isn't possible to get a hold of some device that will throw a relay every time the current goes below a hundred volts. It seems to me that it ought not to be too big a problem. Perhaps we can locate some kind of voltage sensing device that will not just move a needle on a dial, which we of course already have, but will actually trip a relay, that will in turn cut out one line and throw in another. Now if you can get enough relays in sequence you can do just about anything. What we have is a 5000 watt transformer, which breaks 220 volts down to 110 volts. Our 220 comes in at about 135 volts from 6:30 pm to 9:30 pm and drops even lower than that in dips throughout the day when machinery is turned on between us and the power plant, which is 60 miles away. There is nothing we have that would be disturbed by the current being shut off or switched over to another line, but the main thing is for the current to be shut off when the voltage drops low enough to burn out a motor. Some kind of thermostatic device that would throw out the motor through overload is possible, but is far too insensitive. The main thing is a device that will cut a line out when the voltage goes below a hundred volts. We would connect it to the output and connect the relay to the input so that whenever the voltage went below 100 volts it would simply cut the whole thing out.

A little more refined device would be one which would shift the current down to the next transformer tap. All of this would be simpler, it seems to me, than a device which would actually turn the mechanical rotar on this transformer, which

takes a good deal of torque.

Now the degrees of turns are about 30 degrees...for each notch. For an input of 220 to an input of 145 we have to adjust 180 degrees of change.

Perhaps I should add that being on the very end of the electrical line which comes from 60 miles away through the second largest city in the country, and then through our village before reaching us, our current just isn't too steady. Perhaps the greatest problem we face is that the government tax on electricity is not so much per kilowatts used as the number of different electrical appliances possessed. Thus all the corn mills in the village have one huge machine each which really pull the current down every time they start up. This is why our current fluctuates between the unreasonable limits of 60 volts to 100 volts.

Now it is even more important that we solve this problem, because we are attaching a pump to the water system in order to have a pressurized water system, and hot running water. We do not want the pump to burn out. Heretofore we have always unplugged the refrigerator between the hours of 6 am and 10 pm, but water, of course, is more important than refrigeration.

Thank you for all the work you are going to for us. We wish the problem were an easier one. But of course it is precisely because we are stymied that we turn to you.

Sincerely yours,

Ralph

Ralph D. Winter

(signed in his absence by his wife)

DATA INTERNATIONAL II (B)

Voltage Regulation

With the aid of the additional information obtained through the exchange of letters, a consultant was able to analyze the problem of the fluctuating voltage posed by the missionary in Guatemala. His suggested solution is given in Exhibit 6.

In May, 1966, a letter was received by DATA International from a missionary at St. Joseph's College in Darjeeling, India, asking for help in correcting a problem of a fluctuating voltage supply at the college. A copy of the letter is shown as Exhibit 7. Since the conditions of the problem and the information requested were not precisely the same as those in the first letter, DATA again solicited the advice of some of their consultants.

Exhibit 6

APR 5 1965

March 30, 1965

Data International Assistance Corps.
437 California Avenue
Palo Alto, California

Attention: Mr. Douglas K. Hayward
Projects Coordinator

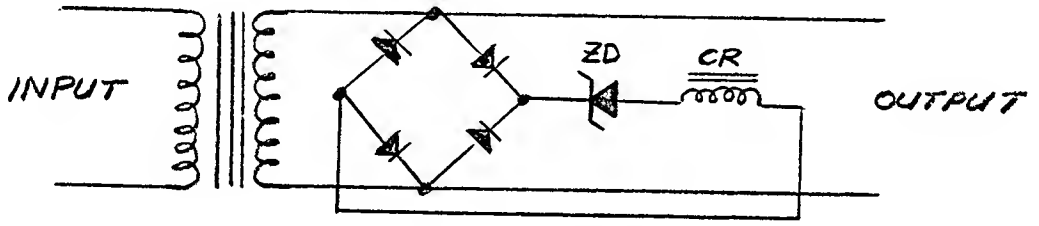
Reference: Problem No. 3030

Dear Mr. Hayward:

In reply to your letter of March 16th regarding Dr. Ralph Winter's problem of maintaining the proper line voltage so as not to destroy the electrical appliances connected to it, I would like to submit the following suggestions.

I see two possible approaches, one opening the circuit to the appliances if the voltage should rise above say 120 volts and a second approach to change the transformer taps as the line voltage changes.

Figure 1 illustrates the first approach.



If the voltage across the transformer secondary should rise above 120 volts the zener diode would conduct and the relay "CR" would energize opening the relay contacts in the appliance side of the transformer. When the voltage dropped below 120 volts the diode would stop conducting and the relay would de-energize closing the contacts again.

The second approach is shown in Figure 2.

Exhibit 6 (Continued)

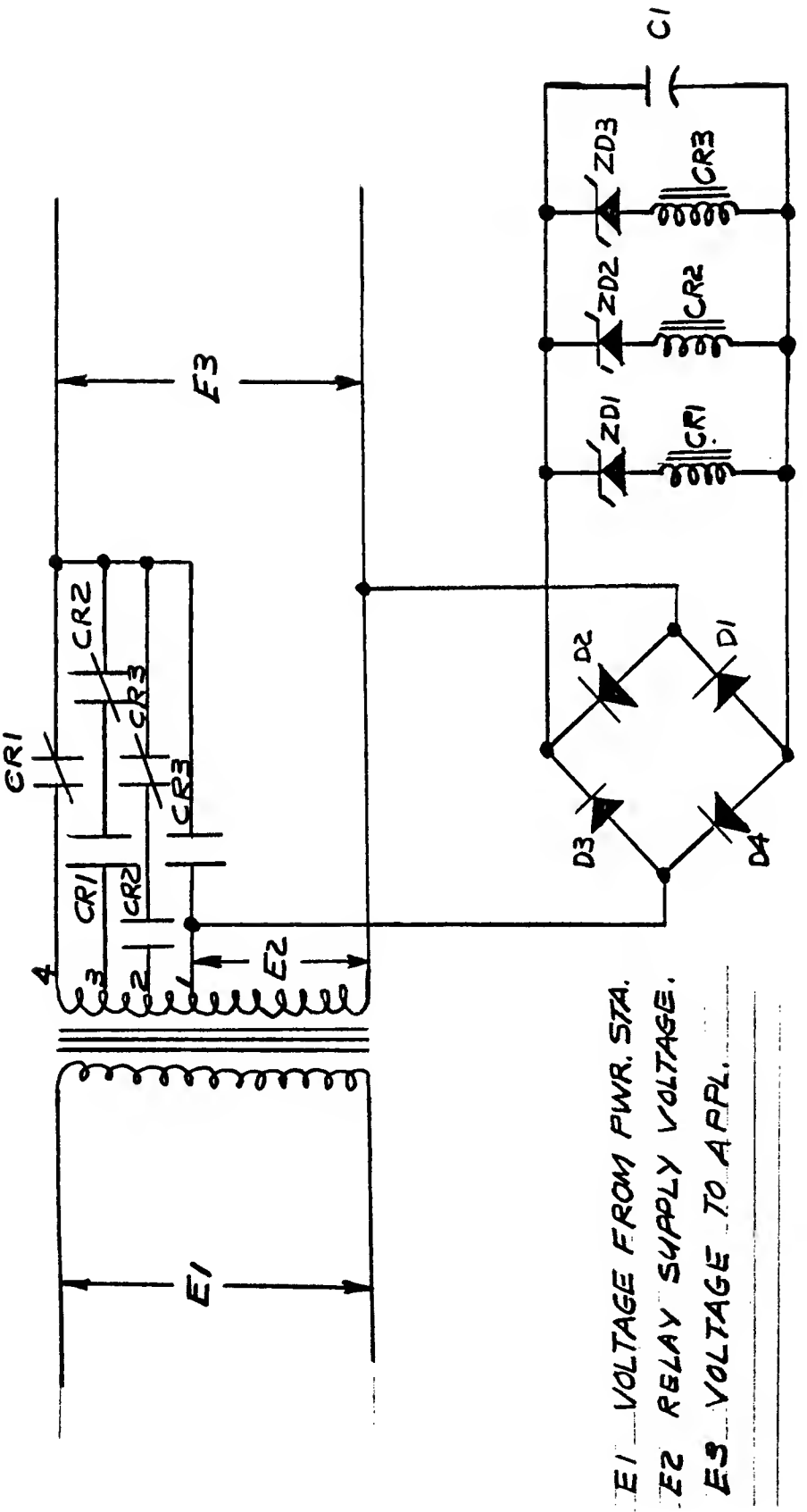


FIGURE 2

With E1 normal (220v), E2 will be sufficient to cause ZD1, ZD2, and ZD3 to conduct thereby energizing CR1, CR2, and CR3. These relays are shown in there normal de-energized condition.

With all relays excited only the first tap will deliver the desired output E3. As the voltage from the power station (E1) drops ZD3 will no longer conduct and CR3 will de-energize. When this occurs the normally closed contacts in tap #2 will close and E3 will be supplied by tap #2 through the energized CR2 contacts and the de-energized CR3 contacts.

If the voltage from the power station should drop further, ZD2 will no longer conduct and CR2 will de-energize opening the CR2 contacts in tap #2 and closing the CR2 contacts in tap #3. Since ZD1 is still conducting the CR1 contacts in tap #3 will be closed thereby producing an output (E3) from tap #3.

If CR1 should de-energize due to E2 dropping below the level necessary to to cause ZD1 to conduct then tap #3 will open and E3 will be derived from tap #4.

As the voltage from the power station increases up to its normal value at E2 then the various relays will energize changing the taps on the transformer in sequence.

By the proper selection of transformer taps and Zener Diodes this system should prevent the appliances from burning out by maintaining the proper line voltage for these appliances.

Figure 2 shows a transformer having a tapped secondary (output) winding, however, if the tapped winding is on the primary (input) side the same theory of operation will apply except that the bridge will be connected across the points indicated by E3, E1 in the figure will then go to the appliances.

Very truly yours,

I. M. Delta*

*Name disguised.

St. Joseph's College
P.O. North Point
Darjeeling

JUN 1 1966

May 25, 1966.

13

★ 5303

Exhibit 7

Dear Sir:

Some time ago I heard about "DATA INTERNATIONAL" from a fellow Canadian, Mr. Horrigan, who lived about 60 miles from here. I am in charge of maintenance in our educational institutions in this area

Here in Darjeeling we have a particular problem with fluctuating voltage. The city supply which is listed at 220 volts 50 cycle, may fluctuate from 170 to 240 V. due to overloading of lines and a short supply of water at certain times of the year. As you know this is very hard on certain types of electrical equipment, especially sealed unit refrigerators which fail to start under load, at a low voltage, and may burn out.

I have read about automatic transformers using saturating cores and condensors but no moving parts. Could these be constructed in a rather well equiped workshop which I have at my disposal? Is it practical to make these big enough to handle 5 to 10 K.V.A. for a whole building or would it be more practical to have a small one, say 500 watts, at the various machines and appliances

Hard regulated transformers are not practical because one never knows when the voltage will change.

Would it be possible for you to send me detailed blue print and specifications

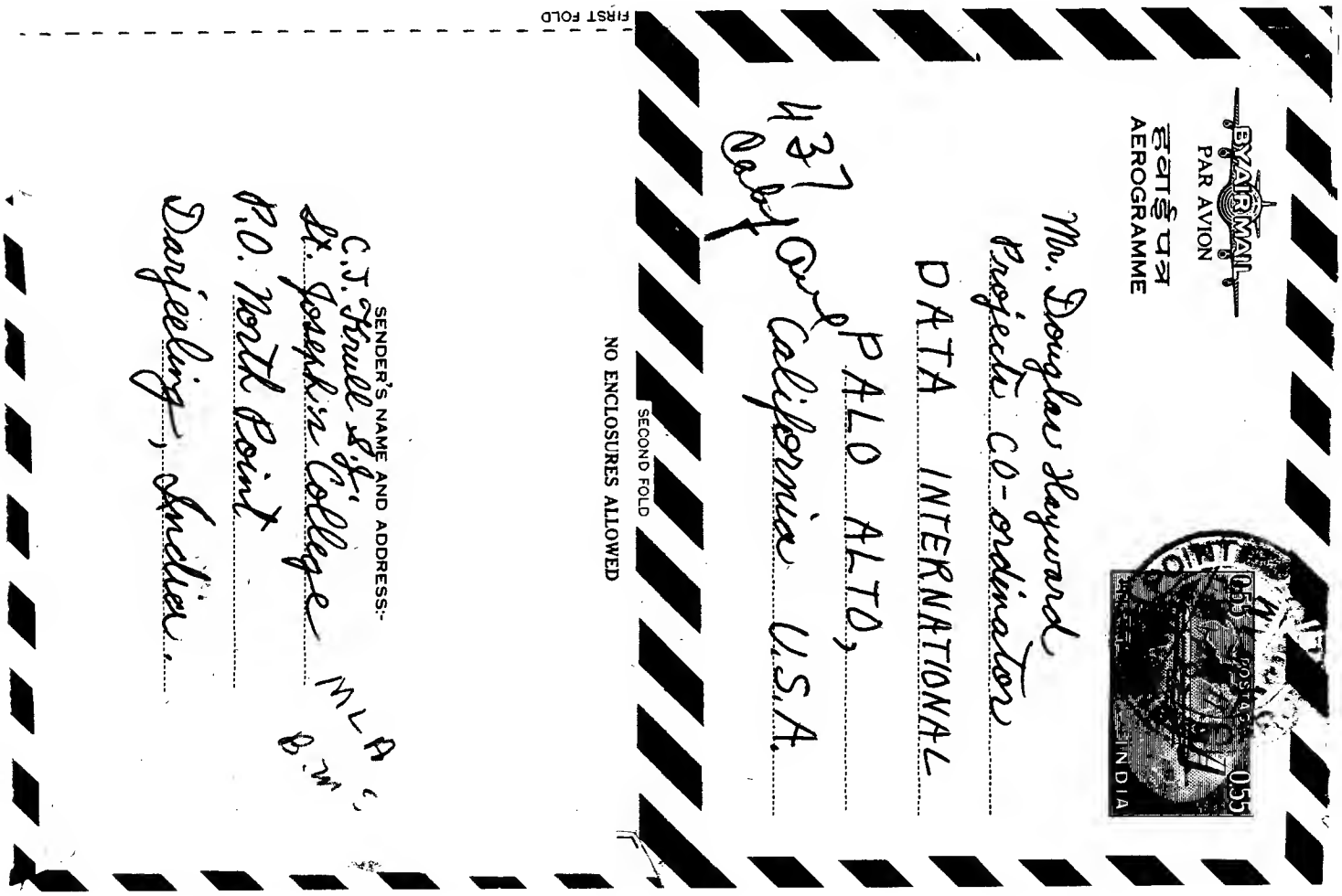
1. to make a 500 watt automatic transformer.
2. " " " 5000 " " "

Or would you suggest automatic mechanically regulated transformers with moving parts? (These would be slower and give more trouble?) any suggestions?

Hoping to hear from you

Sincerely
C. J. Krull S.J.

Exhibit 7 (Continued)



DATA INTERNATIONAL II (C)

Voltage Regulation

In response to their request for advice on the problem of the fluctuating voltage at St. Joseph's College in Darjeeling, DATA received a reply from a consultant, a copy of which is given in Exhibit 8.

Exhibit 8

Ref: CJKroll 5-25-66

July 2, 1966

Data International
Palo Alto, California

Sirs:

Mr. Kroll's letter concerning his voltage variation problem is most interesting, but unusual only since his problem must be solved economically. He does have at his disposal, it is noted, shop facilities. This helps.

First, we should look at the motors involved. Motors are usually designed for a given ratio of voltage to frequency, in this case, 220 volts/ 50 cycles, or 4.4. Commercial motors should operate satisfactorily within ± 10% of the designed voltage, or frequency should either fluctuate. Obviously one cannot expect good operation with full excursion of both voltage and frequency simultaneously, this is too much.

Second, we should look at the power system. Any large load starting, or stopping, on a weak power system will cause large voltage (and perhaps frequency) surges. Fortunately these swings are usually of short duration, and a refrigerator can survive them. More serious is the gradual loading (or unloading) of the system, since this situation can cause very long time voltage depression or elevation. I believe this latter is Mr.Kroll's situation.

Constant voltage transformers are complicated and expensive either to buy or to make. Since they are "tuned" to a given frequency they work well at that frequency, but not well at all at a frequency much removed from their designed frequency. They are fast (0.1 second). I do not recommend their manufacture in a shop, although it can be done, nor do I recommend their purchase because of their cost. In the United States they are generally used for critical areas, such as instrumentation.

Automatically, mechanically operated transformers are reliable, can be purchased fairly economically (especially in large sizes) and are reliable. Mr.Kroll's voltage variation (170-240) is a minus 23% to a plus 9%. Since the motor is good for ± 10% we need supply only a +13% boost, and no bucking voltage. Since the current needs no help, we need only 13% of the kva of the main transformer (or circuit, if he has no transformer). One does not need the full 500 va or 5 kva Mr. Kroll speaks of, but only 13% thereof.

JUN 5 1966

Exhibit 8 (Continued)

For one refrigerator, I would like to see Mr. Kroll experiment in the following manner. Buy, or construct, a simple fixed transformer having about 75-100 va capacity, with a voltage ratio of about 220 to 35. The 220volt winding would be connected across theline directly, while the 35 volt winding would be in series with the feeder to the refrigerator. This, you see, adds 35 volts to the refrigerator line, which would obviously bring his 170 voltsup to 205, well within range of the motor design. Obviously we cannot leave this boosting voltage in the line when the system goes to its high of 240 volts, or we will have 275 volts on the refrigerator which would be deadly. We need, hence, a contact making voltmeter, or a calibrated relay to sense the line voltage at about 205 volts and cut off the boost until such time as the need for boost reappears. I like the use of the relay, since it is cheaper and perhaps more reliable. AC voltage sensing relays are a bit expensive, whereas DC relays are cheaper. I have used a simple slug-adjusted telephone relay (cost $3.00) for this purpose. Since we have no DC, we must insert a simple silicon, copper oxide or germanium rectifer to obtain Dc, this is a small problem. In the above approach we have all the elements of a commercial step voltage regulator - except we have only one step. The transformer must be low reactance, bell transformers with their reactance will not do.

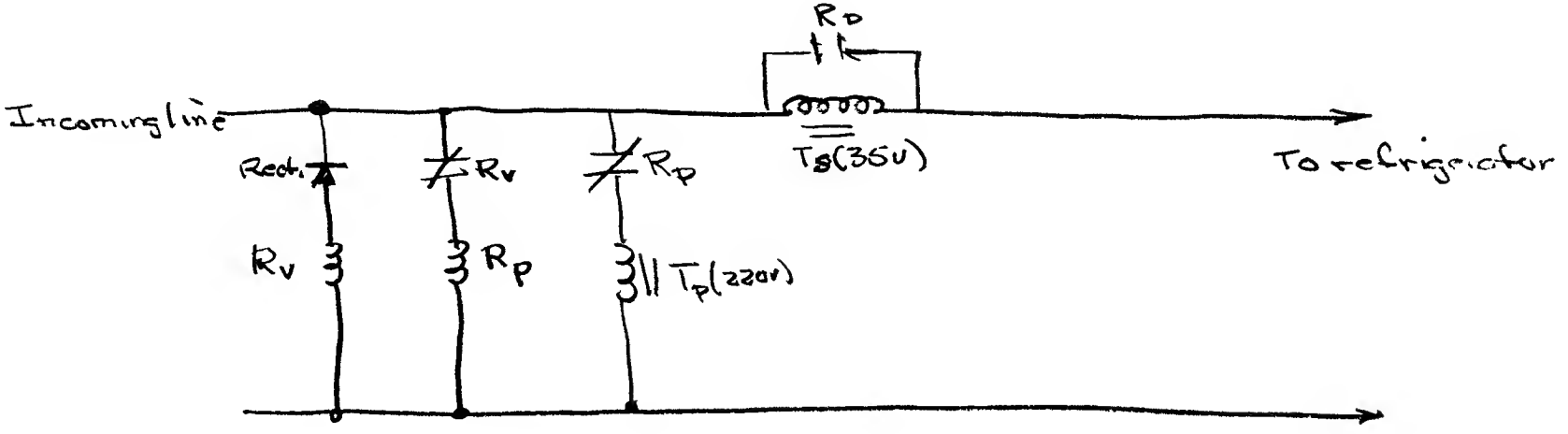
For the full 5 kva for the entire building, the approach would be identical to the above, only larger units. One should note that light bulbs, radios, etc, are sensitive to over voltage, their life is shortened by the square of the overvoltage, i.e.,$(240/220)^2 = 1.19$ which tells us a lamp operating at 240 volts will have 19% shorter life than it will have at 220 volts.

I will be interested in learning of Mr. Kroll's success, or problems, if any. Since refrigerators are expensive, Mr. Kroll may wish to try his regulator on a dummy load (2.5 amperes at 220 volts through a piece of baling wire) to prove it out!

Good luck,

U. R. Wye*

*Name disguised



Rect. = rectifier, 100 ma. radio type

R_V = Voltage sensing relay, DC, telephone type, adjust to pick up at 205 volts.

R_P = Power relay, 2-pole, 220 V, 10-15 amperes.

T_P = Power boost transformer (Pri. 220 V ± / 1-2 amp) to (Sec. 35 V. ±, low reactance / 5-6 amp)

Note:- relays are shown for low voltage situation, i.e, R_V has not picked up, R_V's contact to R_P is closed, so R_P is picked up, closing contacts on Transformer primary, and opening shorting contact around transformer secondary.

Note:- R_P contact to transformer primary not really required